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AN APPLICATION OF THE VIRTUAL POPULATION TECHNIQUE TO PENAEID SHRIMP [1]

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ABSTRACT

Commercial catch statistics for brown shrimp (*Penaeus aztecus* Ives) from a restricted area along the Texas coast were examined by using the virtual population technique. The sum of all catches from a single year class was used as a minimum estimate of population size at the time of recruitment. The conversion of catches from pounds to numbers also made possible maximum estimates of the exploitation rate for all periods after recruitment. Monthly catches of shrimp of each size group were compared for the years 1961-66, and weights were converted to value by using the mean price per pound for each size group for the period.

Comparisons of the percentage of a year class harvested at each size with the percentage of the gross value contributed by each size group may aid in making decisions concerning the management of shrimp stocks.

INTRODUCTION

An important objective of fish and shellfish population studies is to determine the size at which individuals should be caught to provide maximum yields. Techniques commonly used to estimate optimum size at harvest require detailed knowledge of growth and mortality rates. When such information is not available, preliminary assessments of optimum size can be made from landing statistics, provided that these reflect the age or size composition of catches. The virtual population technique (Fry, 1949) is used in the following discussion to compare size composition of harvests of brown shrimp (*Penaeus aztecus* Ives) from Texas waters and to estimate maximum rates of exploitation. Relations between size at harvest and value of landings are also examined.

THE VIRTUAL POPULATION TECHNIQUE

A virtual population is defined as the number of individuals in a stock at a given time that will be caught later by the fishery (Fry, 1949). The sum of catches from a year class is an estimate of the virtual population at the time the year class became vulnerable to the fishery. It differs from the actual population size by the number of individuals that die from natural causes. Hence, the lower the rate of natural mortality, the closer the virtual population is to the actual population.

Use of this technique necessitates several assumptions. The population being studied must be well defined or, if the population is mobile, movement into the population must equal emigration from the population. Landing statistics must reflect accurately the size composition and magnitude of catches. Catches from each year class must be recognized. If the technique is used for shrimp population studies based on commercial landings, grading methods must be uniform throughout the study area.

When the catches contributing to the virtual population for a year class are considered by time periods, rates of exploitation can be calculated. The number caught during a given period divided by the number in the virtual population at the beginning of the interval is a maximum estimate of the rate of exploitation for that period. Estimates of exploitation rates are maximal because the virtual population is a minimum estimate of the actual population.

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APPLICATION OF THE TECHNIQUE TO A SHRIMP POPULATION

Shrimp landing statistics gathered by the Bureau of Commercial Fisheries and published monthly in *Gulf Coast Shrimp Data* provide information suitable for estimating virtual populations of shrimp in relatively small areas of the Gulf of Mexico. These data are tabulated according to species, weight, and size of shrimp landed, as well as by water depths and areas from which catches were made. The purpose of this paper is to demonstrate an application of the virtual population technique in which these landing statistics are used. Landings of brown shrimp (*Penaeus aztecus* Ives) from statistical areas 18 and 19 (Fig. 1)

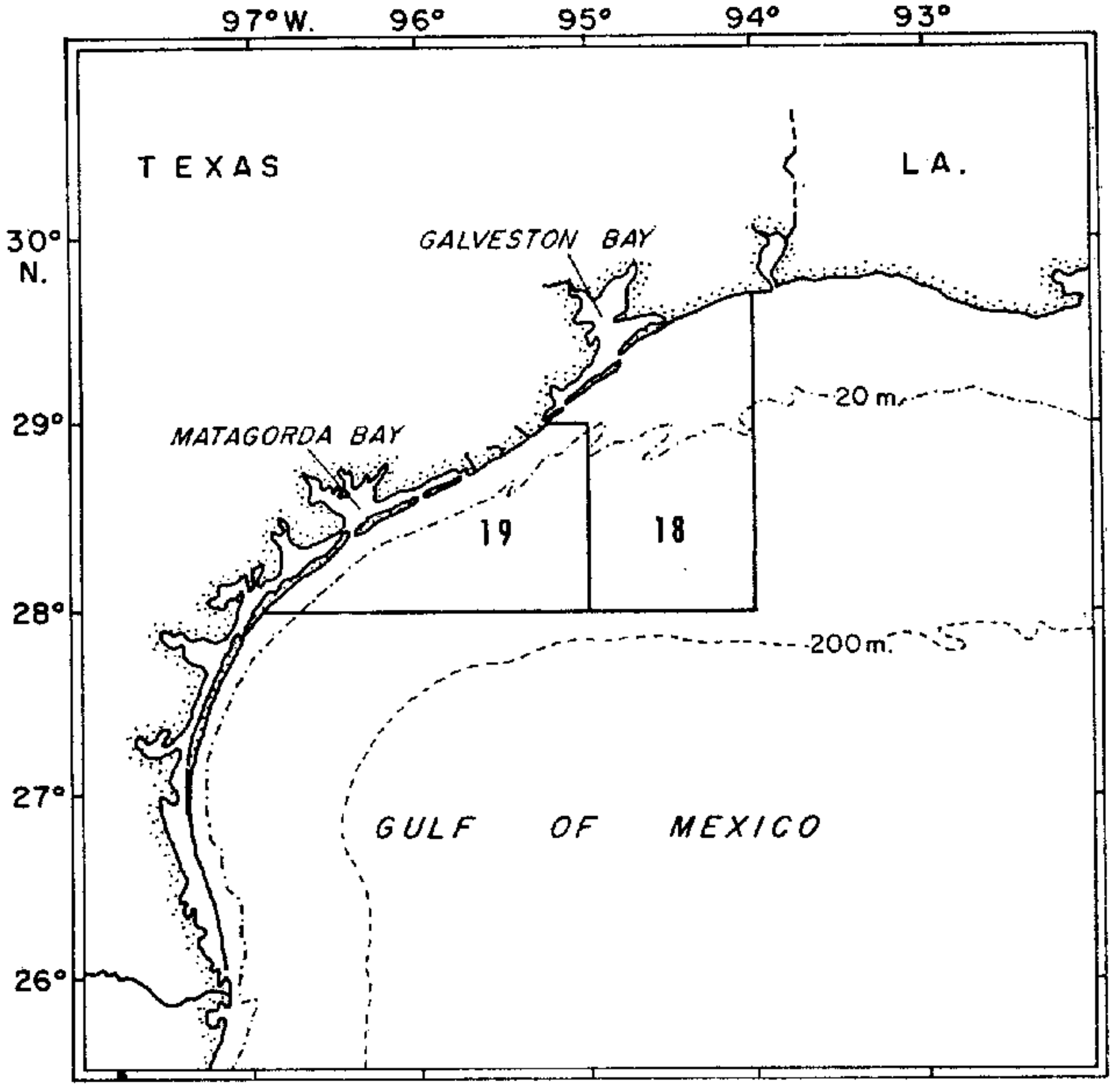

Figure 1 — Area of the Texas coast from which brown shrimp landings were tabulated (Kutkuhn, 1962).

were used in the calculations for the following example. Catches of bait shrimp from bay systems adjacent to areas 18 and 19 were also included. Estimates of bait catches in the Galveston Bay system were made from the results of a survey of bait landings (Berry and Baxter, 1967), and those from Matagorda Bay were based on the number of boats operating each year.

The total weight of shrimp landed in each size group (number of headless shrimp per pound) from May 1961 through September 1966 was arranged in tabular form by months. The arrangement of the data is represented schematically in Figure 2. Landings in pounds were then multiplied by the midpoint of each size group to obtain numbers of shrimp landed.

Figure 2. Schematic representation of the arrangement of landings data.

Heavy lines are divisions between year classes.

Number per pound	Year class / Months																							
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
>100 (bait)	←	—	—	—	X	X	X	X	X	X	X	X	X	X	X	X		—	—	—	—	—	—	→
>67					X	X	X	X	X	X	X	X	X	X	X	X								
51-67	←	—	—	—	—	X	X	X	X	X	X	X	X	X	X	X	X		—	—	—	—	—	→
41-50						X	X	X	X	X	X	X	X	X	X	X	X							
31-40	←	—	—	—	—	X	X	X	X	X	X	X	X	X	X	X	X		—	—	—	—	—	→
26-30							X	X	X	X	X	X	X	X	X	X	X	X						
21-25	←	—	—	—	—	—		X	X	X	X	X	X	X	X	X	X	X	X	—	—	—	—	→
15-20								X	X	X	X	X	X	X	X	X	X	X	X	X				
<15	←	—	—	—	—	—	—	—		X	X	X	X	X	X	X	X	X	X	X	X	—	—	→

TABLE 1 — THOUSANDS OF SHRIMP FROM THE 1964 YEAR CLASS TAKEN BY COMMERCIAL FISHERIES FROM STATISTICAL AREAS 18 AND 19 (SEE FIGURE 1).

No./lb. (Heads-off)	1964								1965									
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Total
> 100 (Bait fishery)	17,079	25,346	14,407	1,817	3,151	2,193	450	46	..	..	..	..	..	..	..	..	..	64,489
> 67	11,185	23,902	4,630	282	148	149	1,225	..	..	..	..	..	..	..	..	..	..	41,521
51-67	..	6,518	7,901	2,704	1,256	47	38	28	4	56	28	1	88	..	..	..	..	18,669
41-50	..	6,482	27,287	4,828	2,415	223	78	31	38	32	9	18	313	..	..	..	..	41,754
31-40	..	3,668	60,317	35,473	8,244	1,054	253	342	255	245	175	167	233	..	..	..	..	110,426
26-30	..	..	3,935	40,821	17,126	1,304	402	1,055	464	472	239	1,135	170	1,074	..	..	..	68,197
21-25	..	..	..	13,510	31,575	8,975	1,859	1,286	1,339	175	120	1,028	726	684	1,322	..	..	62,599
15-20	..	..	..	..	8,026	11,724	4,449	1,694	2,642	701	297	999	1,200	989	805	1,349	..	34,875
< 15	..	..	..	..	..	288	186	25	26	4	1	39	75	214	358	316	489	2,021
Total	28,264	65,916	118,477	99,435	71,941	25,957	8,940	4,507	4,768	1,685	869	3,387	2,805	2,961	2,485	1,665	489	444,551

Shrimp entering the fishery between May and April (entries during January through April were negligible) of each year were designated as a year class. These shrimp contributed to the commercial catch through the following September. For the years 1961-65, year classes were separated in the commercial landings statistics on the basis of changes in the number of shrimp landed in each size group. In most cases a marked decline in landings in each size group occurred between year classes. The division of year classes was made between the same months of each year (indicated by the heavy lines in Figure 2). Landings from the 1964 year class are presented in Table 1 as an example. The sum of the landings from a year class is the virtual population estimate for that year class.

The relation between shrimp size and value was also considered because the price per pound paid for shrimp increases with shrimp weight (Fig. 3). The relative value of landings in each size group by year classes was calculated from average price data for the period 1961-66. This average price was used for all years so that the value of landings could be compared directly.

A summary of virtual population estimates, relative values of the year classes, and average size at harvest by year class is presented in Table 2. The relative value of a year class is related closely to the average size at harvest.

TABLE 2 — ESTIMATES OF VIRTUAL POPULATION, RELATIVE VALUE, AND AVERAGE SIZE AT HARVEST FOR FIVE YEAR CLASSES OF BROWN SHRIMP.
(The numbers in parentheses are exclusive of bait shrimp catches.)

Year class	Virtual population (thousands of shrimp)	Relative value (thousands of dollars)	Average size (no./lb.)	Relative value per 1,000 shrimp (dollars)
1961	338,437 (230,469)	5,200 (4,300)	61.2 (38.4)	15.36 (18.66)
1962	481,238 (365,455)	7,900 (6,900)	58.7 (42.6)	16.42 (18.88)
1963	636,443 (529,786)	12,400 (11,600)	47.8 (35.3)	19.48 (21.90)
1964	444,551 (380,062)	8,900 (8,400)	47.6 (37.0)	20.02 (22.10)
1965	814,684 (692,944)	13,800 (12,800)	51.4 (41.2)	16.94 (18.47)

Rates of exploitation calculated for the period of time that shrimp were in each size category are presented in Table 3. Estimates for large shrimp (i.e., < 15, 15-20) are too high, however, because no information

TABLE 3 — MAXIMUM ESTIMATES OF RATE OF EXPLOITATION FOR EACH SIZE GROUP OF BROWN SHRIMP, BY YEAR CLASSES.

Size group	Year class				
	1961	1962	1963	1964	1965
> 100	0.319	0.241	0.168	0.145	0.149
> 67	0.074	0.218	0.051	0.109	0.148
51-67	0.060	0.072	0.076	0.055	0.124
41-50	0.194	0.211	0.105	0.130	0.164
31-40	0.621	0.358	0.478	0.397	0.432
26-30	0.492	0.287	0.418	0.407	0.417
21-25	0.390	0.618	0.522	0.629	0.724

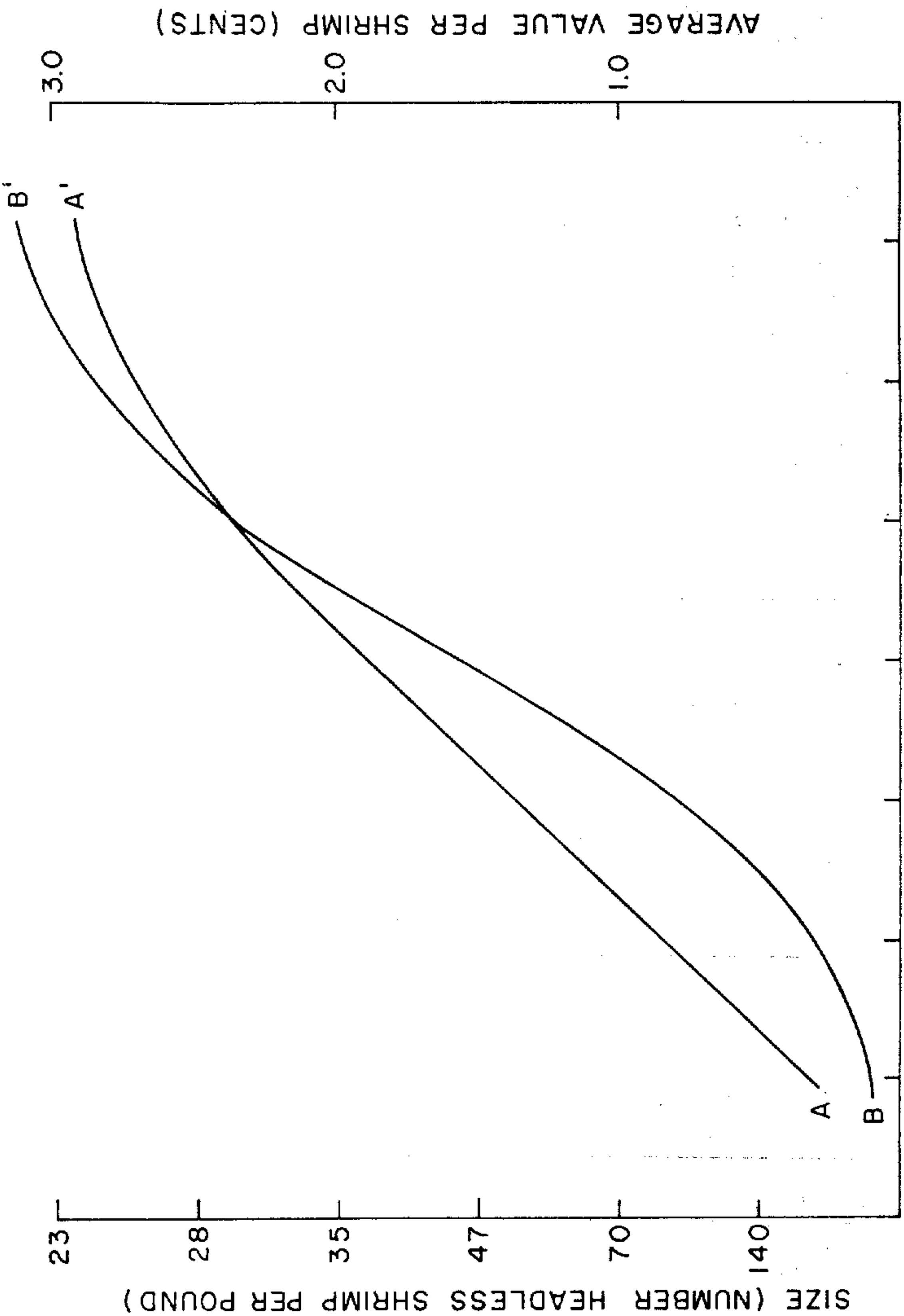

Figure 3 — Approximate growth in weight (A-A') and corresponding increase in value (B-B') of brown shrimp entering the fishery in May. Value was calculated from average exvessel prices in 1961-66, excluding bait shrimp.

is available on the number of shrimp that escape capture at large sizes (less than 15 to the pound). Estimates which are most seriously biased were omitted from Table 3. The average time required for a shrimp to pass through each size group was calculated by using a hypothetical growth curve for brown shrimp—length at time $t = 190\ (1 - e^{.07\ (t - to)})$. Exploitation rates were then converted to a weekly basis (Table 4).

TABLE 4 — MAXIMUM RATE OF EXPLOITATION PER WEEK (PERCENTAGE) BY SIZE GROUP.

Size group	Year class				
	1961	1962	1963	1964	1965
51-67	2	3	4	2	6
41-50	10	10	5	6	8
31-40	27	14	19	17	17
26-30	22	12	18	17	18
21-25	5	9	7	9	11

DISCUSSION OF RESULTS

An advantage of the virtual population technique is that it gives us an estimate of the size of an entire year class. These estimates are particularly useful as a basis for percentage comparisons. By using comparisons of the percentage of the virtual population harvested at different times and sizes, we can obtain information regarding the relation between time of harvest and size at harvest, and the relation between size at harvest and value.

The percentage of the virtual population that was captured each month is recorded for each year class in Figure 4. Most shrimp taken from each year class were caught during the first 4 or 5 months after they entered the fishery. Also, the proportion harvested each month after December was consistently small. The distribution of landings was similar from year to year, but small changes in the timing of harvests made appreciable differences in the weight of the catch.

Expressing the landing data as a percentage of the virtual population is also convenient for comparing the size distribution of landings among years. From the shrimp landings the percentage of the virtual population taken from each size category was calculated for each year class. Catch data for the 1962 and 1963 year classes are compared in Figure 5 to illustrate annual differences in sizes harvested.

Relative values of landings in each size group are presented as percentages of the total gross value for the 1962 and 1963 year classes in Figure 5.

The comparison between the 1962 and 1963 year classes illustrates possible applications of these calculations. The number of shrimp caught from the 1963 year class was 32 percent larger than the number caught from the 1962 year class (Table 2). Accompanying this 32 percent increase in catch was a 57 percent increase in relative value. Value increased almost $2 million more than would be expected from the increase in numbers of shrimp alone. Much of the 1962 catch was taken from the smaller size groups and contributed only a small proportion of the income from that year class (Fig. 5). In contrast, the numbers of the 1963 year class harvested from the 15-20, 26-30, and 31-40 size groups contributed a large proportion of the value of that year class. As a result of the differences in sizes harvested, the value per 1,000 shrimp was considerably higher in 1963 than in 1962 (Table 2).

The virtual population technique permits an investigator to examine the size composition and seasonal distribution of landings from a year class. A change in the size of shrimp harvested is frequently a goal of regulatory measures. This method of examining catches may be useful in evaluating such regulations. Maximum rates of exploitation are a basis for evaluating rates calculated by other methods.

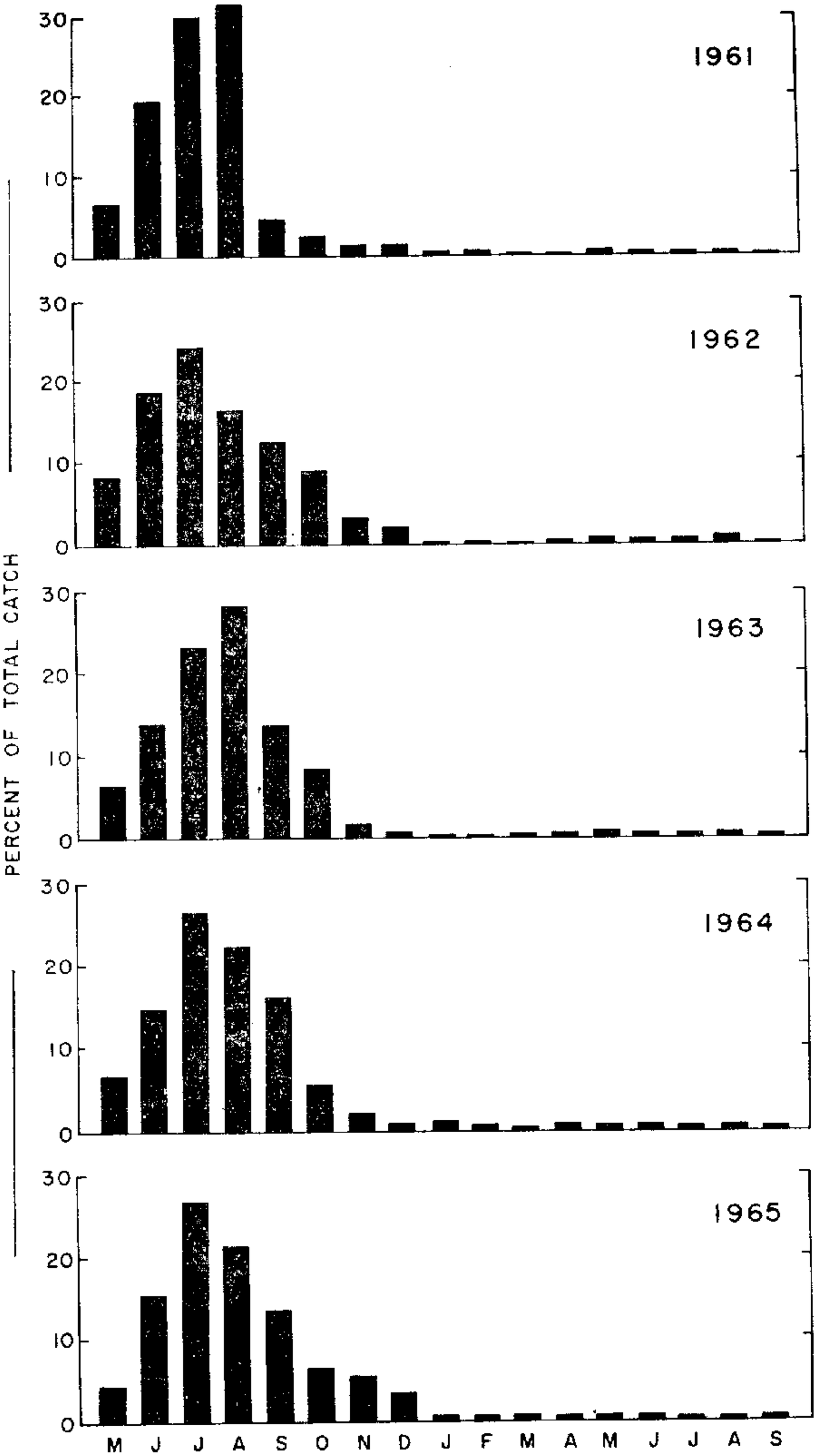

Figure 4 — Percentage of total catch in numbers of shrimp taken each month, by year classes.